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THE SIZE AND FREQUENCY OF STOMATA IN RELATION TO DROUGHT RESISTANCE IN WHEAT

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THE SIZE AND FREQUENCY OF STOMATA IN RELATION TO DROUGHT RESISTANCE IN WHEAT.

J. E. Birdsall

INTRODUCTION

The problem of breeding varieties of wheat having higher yielding capacity than existing ones under conditions of limited moisture supply is extremely complex. The ease of recognition of desirable types is important in determining the complexity of any breeding problem. Since drought resistance is, in common with most economically important characters of crop plants, quantitative in its expression, it is impossible to select for it in early generations, with any degree of confidence. Comparative yield trials, which at present furnish the only measure of drought resistance, are, at best, expensive and time consuming, and, by this method, only a few hundred strains can be tested at one time. Investigational work at the University of Alberta has aimed at refinement of the methods of selection in early hybrid generations, so that the general level of yielding ability of strains going into the yield trials might be raised. If a relationship could be established between drought resistance and one or more easily measured or readily observable characters, selection in breeding material would be greatly facilitated. During the past five years the selection value of several characters has been investigated.

Neatby and McCalla (12) established a negative relationship

between yielding capacity and protein content in wheat. This relationship can not well be used for selecting in early generations, but in later generations, by discarding strains having protein contents higher than necessary from a quality standpoint, the lowest yielding strains are eliminated.

Resistance of varieties and hybrid strains to atmospheric drought has been tested in a drought machine described by Kenway and Peto (6), but it has not been found possible to obtain results which are sufficiently consistent to be of value for selection purposes.

The tillering capacity of a large number of varieties and hybrid strains has been determined. Significant varietal differences have been established in each of three years, but the interaction of years and varieties involves so great an error that this character has no selection value.

Peto (14) tested the tolerance of seedlings to sugar solutions and established significant varietal differences for this character, but did not attempt to relate it to drought resistance.

A study has been made of the comparative root development of a number of varieties and hybrid strains. The results are interesting and some relationship with yield is indicated, but the method is slow and laborious.

Peto (14) made a preliminary study of stomatal frequency per unit leaf area in 81 varieties and hybrid strains in 1936. This study has since been extended and, in addition, the length of stomata, together with the relation of soil moisture content to stomatal length and frequency, has been investigated. A few workers have attempted to relate these characters to drought rebetween yielding capacity and protein content is known. This relationship can not be used for selection in early generations, but in later generations, to discriminate strains having protein contents higher than necessary from a quality standpoint, the lowest yielding strains are eliminated.

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A study has been made of the comparative root development of a number of varieties and hybrid strains. The results are interesting and some relationship with yield is indicated, but the method is slow and laborious.

Peto (14) made a preliminary study of stomatal frequency per unit leaf area in 11 varieties and hybrid strains in 1930. This study has since been extended and, in addition, the length of stomata, together with the relation of soil moisture content to stomatal length and frequency, has been investigated. A few workers have attempted to relate these characters to drought resistance and several have studied the effect of varying moisture conditions upon them. The literature will be reviewed very briefly.

Most investigators are agreed that a limited moisture supply results in plants having an increased number of stomata of reduced size, as compared to plants growing under more favorable moisture conditions. Investigators reporting increased numbers of stomata, or smaller stomata, or both, with unfavorably low moisture supply are; Koken, Kohl, Zalenski, Heuser, Tumanov and Rippel, according to Maximov (9), Yapp (19), Mariana (8), Salisbury (15), Van De Roovart and Fuller (18), and Bruner and Weaver according to Van De Roovart and Fuller. Salisbury studied woodland flora and concluded that humidity is the most important factor in determining the length of stomata and their frequency per unit area of leaf surface. Van De Roovart and Fuller grew barley, wheat and corn at seven different moisture levels, three of them below, and four above the wilting percentage. They found that under optimal moisture conditions there was a low stomatal frequency, this increasing with either an increase or a decrease in soil moisture.

On the other hand Duggar (3) reports that in wheat and corn grown in sand cultures at varying conditions of moisture supply, the plants grown at the higher moisture levels had more stomata. Zeigler, according to Salisbury (15), studied Carex spp. and found that those growing under most xerophytic conditions had fewest stomata.

Weiss is reported by Miller (10) to have concluded, after extensive investigations, that the conditions under which plants are grown do not influence the size or frequency of stomata.

Kiesselbach (7) studied corn varieties and found no significant effect on the length of stomata which could be attributed to soil moisture or soil fertility.

Kolkunov, according to Maximov (9) and Boulsonoff and Orlowski (2) conclude that, of the wheat varieties they studied, the more drought resistant of them were characterized by shorter stomata than was the case for the less drought resistant varieties. The latter authors consider the character, stomatal length, useful in evaluating the drought resistance of wheat varieties. Pavlov (13) agrees that a negative relation exists between size of stomata and drought resistance in winter wheat, but could not establish such a relation in spring wheat or oats. Vasilov (19) attempted to establish a connection between the length of stomata of wheat varieties, their geographical origin and drought resistance, but concluded that no such relationships exist.

No report has been found in the literature of stomata being studied in relation to drought resistance, using the results of yield trials as a measure of drought resistance. In the investigations reported in this paper that was the procedure.

MATERIAL AND METHODS.

All stomatal determinations used in correlation studies were made on the varieties and hybrid strains in advanced yield tests being conducted in connection with the program of breeding wheat for drought resistance. The material in these tests consisted of standard varieties, introductions and hybrids. Most of the introductions were obtained from Russia. In addition to these, stomatal frequencies were determined on 86 varieties in the pre-

liminary drought test, and on 52 varieties in the wheat garden. On 18 of the wheat garden varieties stomatal lengths were determined as well. Complete lists of varieties and hybrids on which determinations were made, together with summaries of stomatal data, will be found in the appendix. In all, approximately 8,000 fields, or 260,000 stomata were counted, and 16,000 were measured for length.

For making counts, a number 8 objective and a number 15 ocular were used on the microscope. The area under magnification was 0.704 square millimeters. For measuring stomata an 8x objective and an ocular screw-micrometer were used. With this micrometer lengths are determined very quickly. A dial is turned which will move a vertical line from one end of a stoma to the other, and the length is read directly from the dial. Using the number 8 objective one unit on the micrometer dial is equal to 1.053 microns.

For the counts made in 1937 upper leaf surfaces were used, but all subsequent determinations were made on the under surface of the leaves. All determinations were made at approximately the same distance from the base of the leaf, the distance being determined by placing the base at the left hand edge of the microscope stage. The leaves were held on 8 x 4 cm. slides by means of thin cardboards, of the same dimensions, glued to one edge of the slide. In the center of the cardboard a hole, one centimeter in diameter, was cut, thus exposing a portion of the leaf. Measurements were made on closed stomata, leaves being placed in darkness for one hour to ensure closure. Ten stomata were measured in each of five leaves of each variety; lengths of entire stomata (not aperture) being determined. The stomata are

in rows and one determination was made in each of ten rows on a leaf. The stomata in one microscope field on each of ten leaves of a variety were counted. Terminal-leaf determinations were made when plants had just headed, subterminal leaf determinations when the plants were in the shot-blade or just heading, and those on seedling leaves when the plants were in the three-leaf stage.

In a study of the relation of soil moisture to stomatal length and frequency, two experiments were carried out in the greenhouse. In the first of these, plants of Red Bobs and Milturum .0274 wheat were grown in one-gallon crocks, one plant per crock, and five crocks of each variety at each of four different soil-moisture contents. In the second experiment five plants, of Red Bobs wheat per two-gallon crock, were grown in four crocks at each of four different soil moisture contents. At the beginning of the experimentsair dry soil was made up to the required moisture content, on the basis of percentage of moisture holding capacity of the soil, and no additional moisture was added while the plants were growing. In the first experiment a mixture of 75% parowax and 25% petrolatum was used to reduce evaporation from the soil surface, while in the second experiment ground cork was used for this purpose. Stomata were measured and counted on terminal leaves in the first experiment and on sub-terminal leaves in the second. Stomatal determinations were made according to the method outlined above except that ten fields instead of one were counted on each leaf in the first experiment. Dry weight of straw produced by each plant was determined at maturity.

VARIETAL DIFFERENCES IN THE LENGTH AND FREQUENCY OF STOMATA.

Miller (10) classified a large number of species and varieties of crop plants and concluded that the number of stomata per unit of leaf surface is, within limits, specific for particular species or varieties. Eckerson (4) and Muenscher (11) found an inverse relation between the number and size of stomata of a given type. Thus Miller's conclusion should apply to size of stomata as well as to number.

Data obtained in the present study were subjected to statistical analysis, and in Table I analyses of individual tests are summarized. Varietal differences are highly significant in every test, with differences in length more significant than differences in frequency in most tests. In Table II complete analyses are given for length and frequency of stomata in three tests in which determinations were made on terminal leaves, and in two tests in which they were made on seedling leaves, and an analysis is given for three tests in which frequency determinations only, were made on subterminal leaves. It is clear that varietal differences are very consistent. The interaction between varieties and tests was used as error, and significant varietal differences were demonstrated in all cases but one. The varietal differences in frequency determined on seedling leaves in two tests were not significant. The error involved in the interaction of varieties and tests is evidently greater for frequencies than for lengths.

Figures 1 and 2 illustrate the striking differences in size and frequency of stomata that were found between varieties. Fig. 3 shows size differences only.

TABLE I.

Summary of analyses of data on length and frequency of stomata in individual field tests. (The analysis of a complete test is given and below it the analysis for the varieties common to 3 terminal, or 2 seedling leaf tests).

		Length (microns)				Frequency (per sq. mm.)			
		Variety Means				Variety Means			
Number of Varieties	Leaf Used	General	Range	F. Value	5% Point	General	Range	F. Value	5% Point
75	Terminal	59.3	52.8-66.2	3.24	1.35	69.8	56.7-95.3	5.3	1.32
31	"	59.7	52.8-66.2	3.64	1.55	68.9	56.7-95.3	7.7	1.52
52(1)*	"	55.3	49.8-60.6	8.90	1.42	48.6	40.3-60.4	3.7	1.38
31(1)*	"	55.9	49.8-60.6	7.54	1.55	53.4	42.7-57.1	5.0	1.52
52(3)*	"	55.6	50.4-61.0	5.54	1.42	47.1	37.4-57.5	3.3	1.38
31(3)*	"	56.3	50.4-61.0	5.09	1.55	47.1	40.0-57.5	3.0	1.52
75(1)**	Seedling	70.9	60.7-77.8	2.35	1.35	21.3	15.6-34.1	8.8	1.32
25(1)**	"	71.3	64.7-76.4	4.66	1.63	20.9	16.5-23.6	3.3	1.57
25(2)	"	75.0	68.6-82.0	5.56	1.63	26.4	22.3-31.4	3.9	1.57
86(1)***	Subterminal					49.1	36.8-68.9	7.0	1.30
86(3)***	"					46.6	34.4-68.0	10.4	1.30
86(4)***	"					42.5	32.5-60.1	9.7	1.30

* (1) and (3) refer to the field replicate of the 1939 tillering test in which the determinations were made.

** (1) refers to 1938 determinations and (2) to 1939 determinations.

*** (1) and (3) refer to the field replicates in the Edmonton preliminary drought test, and (4) in the Castor preliminary drought test, in which determinations were made.

TABLE II.

Analyses of stomatal determinations. (Length in microns and frequencies per square millimeter)

			F	5%	Variety Means	
Variables	D.F.	Variance	Value	Point	General	Range
Length, terminal leaves.						
Varieties	30	595.8	8.15	1.65	57.3	51.0-60.7
Tests	2	7634.0	106.18	3.15		
Varieties x Tests	60	71.9				
Replicates 4)	12	131.7				
Replicates x Tests 8(						
Leaves	4541					
Total	4649					
Frequency, terminal leaves.						
Varieties	30	214.8	2.86	1.65	55.0	49.0-66.2
Tests	2	22432.5	298.30	3.15		
Varieties x Tests	60	75.2				
Remainder	837	21.7				
Total	929					
Frequency, subterminal leaves.						
Varieties	85	414.9	8.45	1.37	46.0	37.5-64.6
Tests	2	4913.0	100.06	3.06		
Varieties x Tests	170	49.1				
Remainder	2322	19.6				
Total	2579					
Length, seedling leaves.						
Varieties	24	938.9	4.3	1.98	73.1	66.7-79.0
Tests	1	9117.0	42.0	4.26		
Varieties x Tests	24	217.0				
Replicates 4)	8	94.2				
Replicates x Tests 4(						
Leaves	3692					
Total	3749					
Frequency, seedling leaves.						
Varieties	24	24.8	1.68	1.98	23.6	19.0-26.5
Tests	1	1933.0	130.61	4.26		
Varieties x Tests	24	14.8				
Remainder	450					
Total	499					

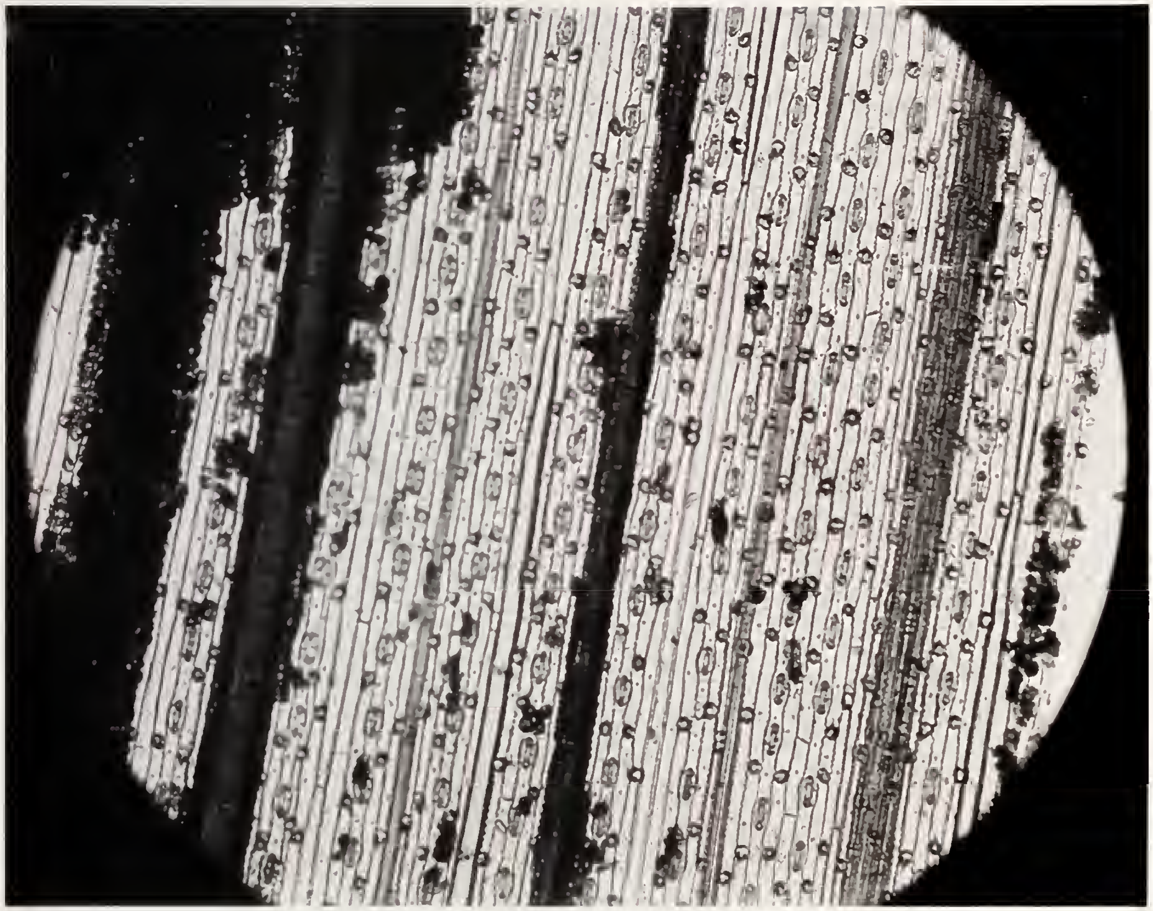

Fig. I. Photomicrograph of one field on a terminal leaf of Milturum .0321 (many small stomata).x 90.

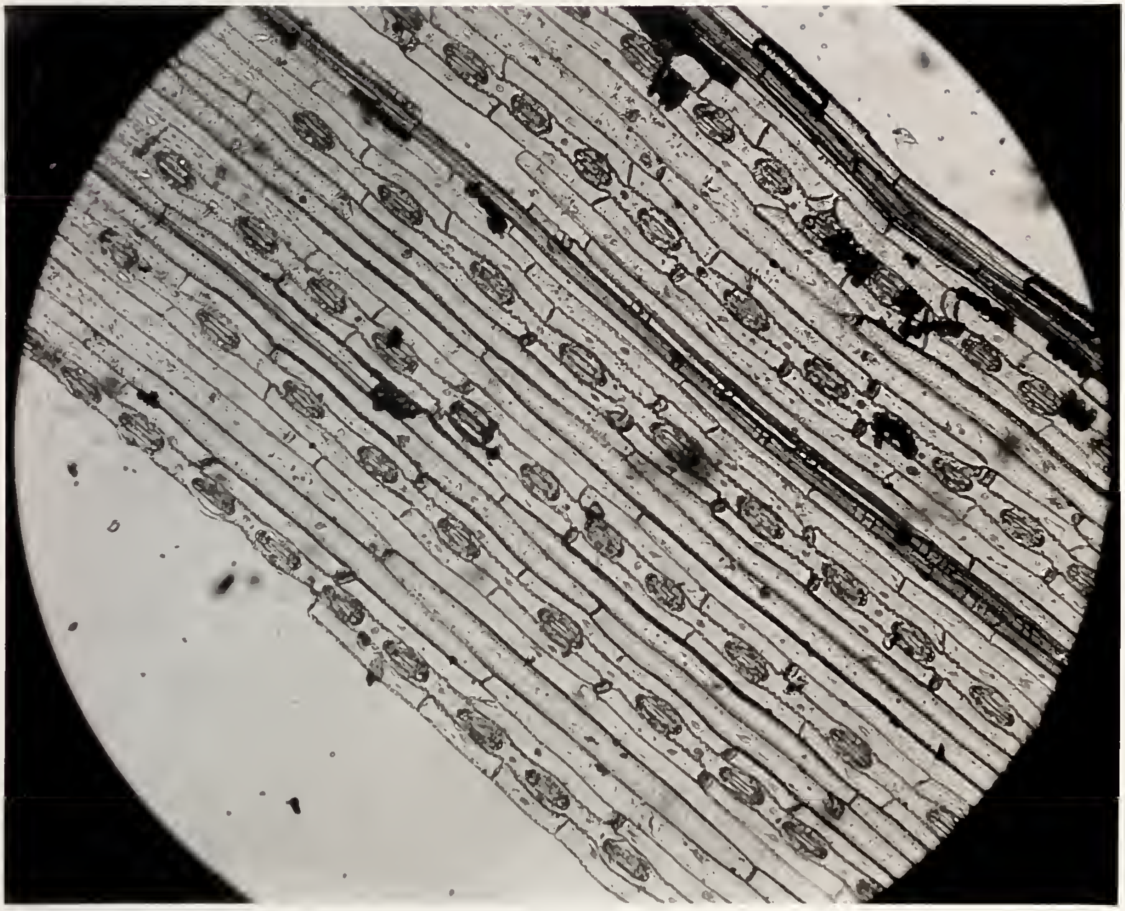

Fig. II. Photomicrograph of one field on a terminal leaf of I-28-60 x Milturum, H-29-39. (Few large stomata).x 90.

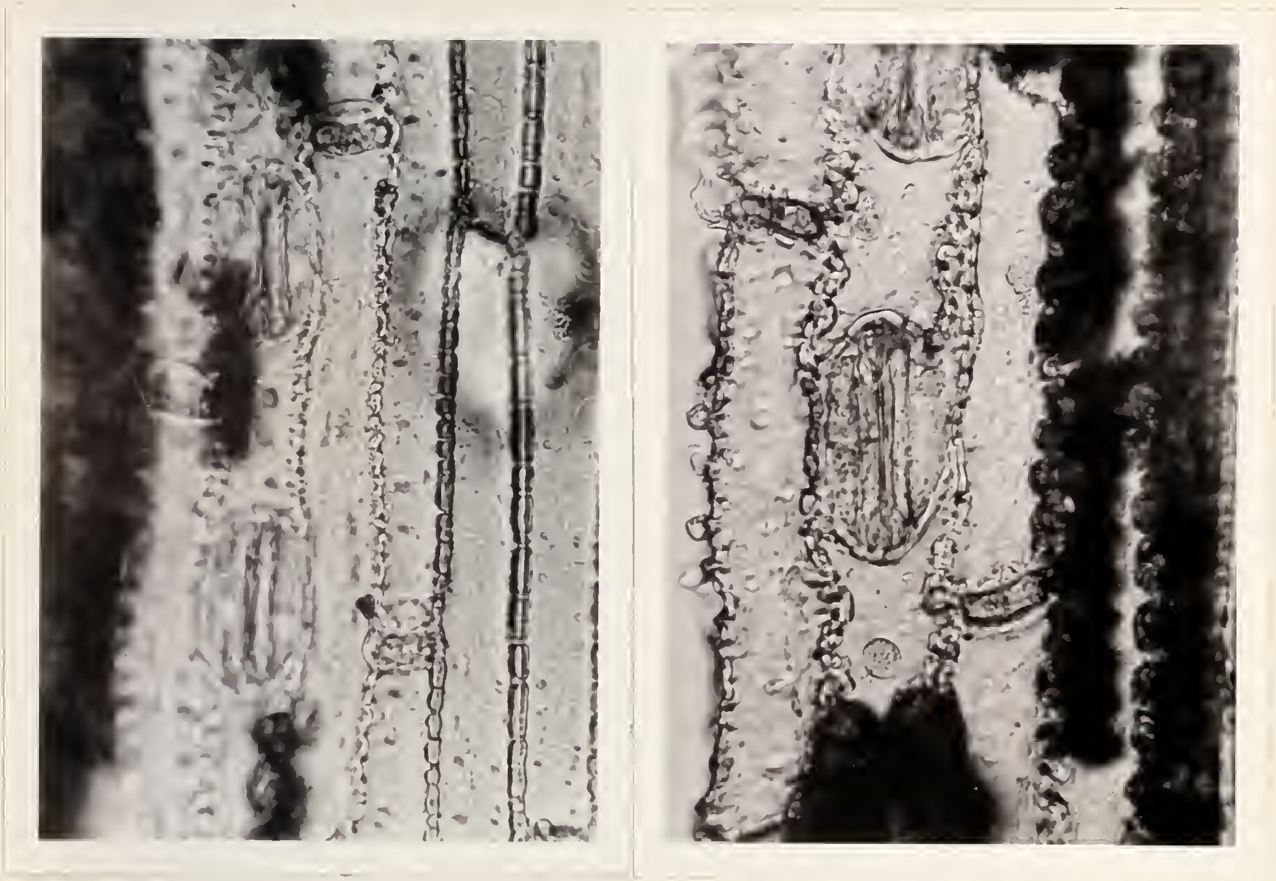

Fig. III. Photomicrographs of stomata of Milturum .0321 (left) and I-28-60 x Milturum, H-29-39 (right).x 450.

In order to investigate the length and frequency of stomata of different selections from individual crosses, data from three tests on terminal leaves were analysed for twelve I-28-60 x Milturum strains and eleven Caesium x Marquis strains. The F values recorded in Table III are based on the interaction between varieties (strains) and tests. The I-28-60 x Milturum strains exhibit a wide range of variation, while no significant differences between Caesium x Marquis strains are apparent.

TABLE III.

Summary of analyses of data on length of stomata on terminal leaves of twelve I-28-60 x Milturum and eleven Caesium x Marquis strains, in three tests.

Cross	Strain Means General	Strain Means Range	F. Value	5% Point	Min. Sig. Difference
I-28-60 x Milturum	58.0	56.7-62.6	7.16	2.26	1.90
Caesium x Marquis	57.0	55.3-59.0	1.55	2.35	2.08

In the analyses of individual tests differences in strains were significant in every case between I-28-60 x Milturum strains but were significant in only one test out of three for Caesium x Marquis strains. In both crosses the mean difference between the parental varieties was found to be 2.6 microns.

Relation Between Length and Frequency of Stomata.

Eckerson (4) and Muenscher (11), as mentioned previously, observed that, in general, plants with few stomata have large ones and those with many stomata have small ones. Such a relation is clearly indicated by the correlation coefficients in Table IV. This relation is more clearly established by the use of terminal leaves than of seedling leaves. Forty-three of the 75 varieties

TABLE IV.

Relation between length and frequency of stomata as measured by the correlation coefficient.

Material	Number of Tests	Year of Determination		r.
		Frequency	Length	
75 varieties, terminal leaves	1	1937	1938	-.55*
52 " , " "	2	1939	1939	-.42*
31 " , " "	3	(1937)1938 (1939	(1938)1939 (1939	-.54*
25 " , seedling leaves	1	1939	1938	-.34
25 " , " "	2	(1938)1939	(1938)1939	-.19

* Exceeds the 1% point.

involved in the first correlation in Table IV are made up of Caesium x Marquis and I-28-60 x Milturum strains. A correlation coefficient was calculated using data on the other 32 varieties which were a miscellaneous group. A much higher correlation was obtained than when data on the entire 75 varieties were used, (r = -.86).

In view of the convenience of using seedling material grown in the greenhouse, the reliability of determinations made on such material was investigated. Two series, one including 75 varieties, and the other 25 of the same varieties, were used. Field determinations on terminal leaves were compared with greenhouse determinations. Correlation coefficients calculated from these data are recorded in Table V. These show that independent determinations of length on terminal leaves, in the field, were closely related, but the relation was weaker when seedling leaves were used. In general seedling leaf determinations were subject to more variability

TABLE V.

Correlation coefficients calculated from stomatal determinations made in different tests on the same series of varieties.

Characters	Correlation Coefficient	
	25 Varieties	75 Varieties
Length and length, terminal leaves	+.77*	
" " " , seedling "	+.51*	
Frequency and frequency, terminal leaves	+.49*	
" " " , seedling leaves	+.26	
Length seedling, and length terminal leaves		+.40*
Frequency seedling, and frequency terminal leaves		+.56*

* Exceeds the 1% point.

than were those made on terminal leaves. Independent frequency determinations were not as closely related as independent measurements. This is to be expected since frequency determinations were shown, in Tables I and III, to be more variable than determinations of length.

Relation Between Yield, and Stomatal Length and Frequency.

Yield data are available, from a number of yield tests, for 31 varieties on which stomatal counts and measurements have been made. Of these, 14 are Caesium x Marquis strains, 12 are I-28-60 x Milturum strains and 5 are miscellaneous varieties.

The relations between yield, and length and frequency are indicated by the correlation coefficients in Table VI. There is a consistent negative correlation between yield and stomatal length. Since there is a negative relation between length and frequency of stomata, a positive relation between yield and stomatal frequency is to be expected; but a significant positive correlation was obtained in only one case out of five.

The value of 1939 yield results for correlation purposes

TABLE VI.

Correlation coefficients calculated from yield and stomatal data.

Variables		
Yield*	Stomata	r**
5 tests	Frequency 1937, terminal leaves	+.11
5 "	" (mean 3 tests) terminal leaves	+.39
4 "	" (" 3 ") " "	+.09
6 "	" (" 2 ") " "	+.09
5 "	" 1938, seedling leaves	+.04
5 "	Length 1938, terminal leaves	-.36
5 "	" (mean 3 tests) terminal leaves	-.40
4 "	" (" 3 ") " "	-.32
6 "	" (" 2 ") " "	-.34
5 "	" 1938, seedling leaves	-.54

* The 5-test means involve Castor fallow 1937, Castor fallow and stubble 1938, Scott 1938 and Edmonton "Tillering test" 1938.
The 4-test means involve Castor fallow 1938, Castor stubble 1939, Scott 1938, and Scott 1939.
The 6-test means involve 2 tests at Castor in 1938, 2 tests at Castor in 1939 and Scott 1938 and 1939.

** For terminal leaf correlations, 5% point = .35
For seedling " " , 5% " = .38

was vitiated by shrivelling of the grain. This was most evident in the test at Castor, on fallow, and was most serious in the Caesium x Marquis strains. No correlation is indicated between 1939 yields and length or frequency of stomata.

Relation Between Protein Content and Stomatal Length and Frequency.

A negative relation between yield and protein content of wheat has been demonstrated by Neatby and McCalla (12), and evidence of a negative correlation between yield and stomatal length has been submitted above. In view of these facts a positive relation between protein content and stomatal length is to be expected. That this relationship actually does exist

TABLE VII.

Correlation coefficients calculated from protein and stomatal data.

Variables

Protein Content*	Stomata				r**
3 tests	1938	Frequency	(mean of 3 tests)	terminal leaves	-.46
3 "	1939	"	(" " 2 ")	" "	-.12
5 "		"	(" " 2 ")	" "	-.48
7 "		"	(" " 3 ")	" "	-.33
5 "		"	(" " 2 ")	seedling leaves	-.32
3 "	1938	Length	(mean of 3 tests)	terminal leaves	+.38
3 "	1939	"	(" " 2 ")	" "	-.23
5 "		"	(" " 2 ")	" "	+.29
7 "		"	(" " 3 ")	" "	+.34
5 "		"	(" " 2 ")	seedling leaves	+.45

* The 3-test means 1938 and 1939 each involve 2 tests at Castor and one test at Scott.
The 5-test means involve Castor stubble 1937, Castor fallow 1938, Castor stubble 1939, and Scott 1938 and 1939.
The 7-test means involve Castor stubble 1937, Castor 2 tests 1938 and 1939, and Scott 1938 and 1939.

** For terminal leaf correlations, 5% point = .35
For seedling " " , 5% " = .38

is shown in Table VII. Though only two of the five correlation coefficients are above the 5% level of significance, two others are very close to it and their consistency lends weight to the indication of a relation. The negative correlation between protein content and stomatal length obtained when 1939 yield data are used is undoubtedly attributable to the high protein content of the Caesium x Marquis strains resulting from shrivelling of the grain. Stomatal length on seedling leaves is more closely related to protein content than is stomatal length on terminal leaves. This is in agreement with the correlations obtained for yield and stomatal length.

The negative relation between protein content and stomatal frequency indicated in Table VII is surprisingly strong as

compared with the positive relation between frequency and yield. Somewhat higher values could be expected since protein content can be determined more accurately than can yield, but if that were the complete explanation larger correlation coefficients for protein content and stomatal length would be expected as well.

Effect of the Moisture Content of the Soil on the Length and Frequency of Stomata.

The literature pertinent to this subject is reviewed in the introduction. In the present study an experiment was carried out which showed that with increases in soil moisture, from an unfavorably low level, the [redacted] stomata in the leaves of Red Bobs and Milturum .0274 wheat increased in size, and decreased in number per unit leaf area, up to a certain point. At the highest moisture level used, stomatal length was reduced and frequency increased in the case of Milturum, while with Red Bobs both length and frequency of stomata were reduced. The size of the plant was reduced with reduction in the size of the stomata. Salisbury (15) and Van De Roovart and Fuller (18) conclude from their investigations that the ratio of the number of stomata to that of epidermal cells remains quite constant. Possibly this should be carried further as the results of this experiment suggest a close relation between size of stomata and general cell size in the plant.

A second experiment was carried out, using Red Bobs wheat, and soil moisture contents as shown in Table VIII, in which the results of the two experiments are summarized. In general they are in agreement. The results of the second experiment show that it was not possible to influence size or frequency of stomata independently of plant size, by altering the moisture conditions compared with the positive relation between frequency and yield. Somewhat higher values would be expected since protein content can be determined more accurately than can yield, but if that were the complete explanation larger correlation coefficients for protein content and stomatal length would be expected as well.

Effect of the Moisture Content of the Soil on the Length and Frequency of Stomata.

The literature pertinent to this subject is reviewed in the introduction. In the present study an experiment was carried out which showed that with increases in soil moisture, from an unfavorably low level, the stomata in the leaves of the Bobs and Mittoran .0674 wheat increased in size, and decreased in number per unit leaf area, up to a certain point. At the highest moisture level used, stomatal length was reduced and frequency increased in the case of Mittoran, while with the Bobs both length and frequency of stomata were reduced. The size of the plant was reduced with reduction in the size of the stomata. Salisbury (15) and Van de Sande and Teller (18) conclude from their investigations that the ratio of the number of stomata to that of epidermal cells remains quite constant. Possibly this should be carried further as the results of this experiment suggest a close relation between size of stomata and general cell size in the plant.

A second experiment was carried out, using Red Bobs wheat, and soil moisture contents as shown in Table VIII, in which the results of the two experiments are summarized. In general they are in agreement. The results of the second experiment show that it was not possible to influence size or frequency of stomata independently of plant size, by altering the moisture conditions

TABLE VIII.

The effect of moisture content of the soil on length and frequency of stomata, and on straw yield, of Red Bobs and Milturum .0274 wheat.

% moisture holding capacity of soil	Length, microns	Frequency per sq. mm.	Straw weight (grams)
Experiment I			
	Red Bobs		
26.4	49.5	44.1	0.30
53.3	56.8	38.8	0.58
71.1	71.4	36.9	0.88
89.2	48.9	28.6	0.21
	Milturum .0274		
26.4	53.1	39.4	0.31
53.3	63.7	36.1	0.66
71.1	62.6	34.0	0.68
89.2	50.7	40.7	0.25
Experiment II			
	Red Bobs		
55.0	50.6	48.2	0.51
60.0	53.1	42.8	0.61
65.0	52.7	40.9	0.62
70.0	53.0	36.0	0.67
75.0	54.0	33.8	0.69

in the soil.

The reduction in length of stomata and the corresponding increase in number which results from a moisture deficiency in the soil is further exemplified by the stomatal data on the subterminal leaves of the preliminary drought test. Determinations of stomatal frequency were made on one field replicate at Castor, where soil moisture up to time of heading was plentiful. Additional determinations were made on each of two field replicates at Edmonton. The test at Edmonton was seeded on land which had

grown a crop of barley in the previous year, and moisture was definitely limiting throughout the season. The mean frequency at Castor was 42.5 stomata per unit leaf area, while at Edmonton it was 49.1 in replicate I and 46.6 in replicate III. The mean yield at Castor was 30.9 bushels per acre and at Edmonton it was 16.8 bushels per acre.

The Relation Between Chromosome Numbers and Length and Frequency of Stomata.

Among others, Blakeslee (1) reports that artificial doubling of chromosome complements results in larger stomata. He considers stomatal size, when measured on comparable leaves, a reliable criterion of chromosome number, when classifying artificially produced polyploids.

Sax and Sax (17), with Tradescantia spp. and Franco (5) with Coffea spp. have shown the existence of a relationship between the number of chromosomes and the size and frequency of stomata; a direct relation with size and an inverse relation with frequency. Sax (16) on the other hand, studied herbarium species of several genera of trees and shrubs and observed that with some exceptions there was a positive correlation between number of chromosomes and number of stomata.

In the 75 varieties of spring wheat classified for length and frequency of stomata (see Appendix A) three varieties of Triticum durum were included. They were Hordeiforme, Pelissier and Mindum. These varieties were observed to have small stomata in large numbers as compared to most varieties of T. vulgare. This suggested a positive correlation between number of chromosomes and length of stomata, and a negative correlation between number of chromosomes and number of stomata.

In 1939 a study was made of 52 varieties of spring wheat selected from the collection being grown in the wheat garden. One variety with 14 chromosomes and two with 56 chromosomes were available. The others were representatives of 28- and 42- chromosome species. The means in Table IX show clearly that, in the material studied, number of chromosomes is correlated positively with length of stomata and negatively with number of stomata. In Table X the results of a statistical analysis of these data are recorded. Differences between groups and also between varieties within groups are highly significant.

TABLE IX.

Relation between chromosome number and length and frequency of stomata.

Number of chromosomes	Number of varieties	Mean length*	Number of varieties	Mean frequency*
14	1	41.7	1	82.1
28	10	47.0	27	64.3
42	5	52.8	22	53.0
56	2	59.2	2	46.6

* Length in microns and frequency per square millimeter.

TABLE X.

Analyses of stomatal length and frequency data for wheat varieties and species.

Variables	D.F.	Variance	F.Value	5% Point
Stomatal Lengths.				
Groups	3	6683.0	120.4	2.74
Varieties	14	827.7	14.9	1.84
Between leaves (error)	72	55.5		
Within leaves	810	14.3		
Total	899			
Stomatal Frequencies.				
Groups	3	3969.0	175.6	2.62
Varieties	48	215.2	9.5	1.38
Remainder	468	22.6		
Total	519			

GENERAL DISCUSSION.

Possibly the most significant phases of the investigation reported herein are, first; the correlation studies between stomatal data and those on yield and protein content, and second; the investigation of the possibility of using determinations made on seedling leaves for selection purposes in breeding material.

Results of replicated field trials, conducted over a three-year period, were used as a measure of drought resistance, and stomatal data were obtained from tests which were independent of those from which yield results were procured. Under these circumstances the evidence of a relationship between length of stomata and yield (drought resistance) may be accepted with confidence.

Protein content can be measured quite accurately, as can length of stomata, while the measurement of the yielding ability of a variety is subject to a high degree of error. This being the case, it may well be that a positive correlation between protein content and stomatal length is a better measure of the relation that exists between yielding ability and stomatal length than is a negative correlation between yield and length of stomata.

The reliability of the correlation coefficient as a measure of a relationship is limited. Among other things, a tendency of varieties to "group" in a scatter diagram, may reduce the value of the coefficient obtained. This danger was particularly great in the present study as a number of strains from each of two crosses were included among the varieties on which determinations were made. This was realized and in cases where a spurious correlation was indicated a coefficient was not calculated.

Higher correlations were obtained between stomatal length

and both yield and protein content when seedling leaf determinations were used, than when the determinations used were made on terminal leaves. This suggests that length of stomata on seedling leaves may prove of value in selecting high yielding strains in breeding material. The plants on which seedling determinations were made were grown in flower pots, and it is difficult to maintain a group of these under uniform conditions in the greenhouse. Improved methods aiming at a more uniform environment are being considered. Such improvements should result in more consistent results between different sets of determinations.

In order to determine more exactly the degree of relationship between yield and stomatal length it will be necessary to use a group of unselected strains from two or more crosses in a further study. The data obtained in this investigation will make it possible to choose parental varieties for such a study intelligently.

The study of stomata and their relation to chromosome numbers in wheat is of interest in the light of similar studies in other genera. It is not improbable, however, that the study may have practical significance. The key to the problem of breeding for drought resistance might possibly be found in interspecific hybridization, just as was done in breeding for rust resistance. The elimination of all durum wheats from our drought tests because of their low yields does not, however, indicate that this would be a promising avenue to explore.

SUMMARY.

Significant varietal differences in length and frequency of stomata were established in all tests. Stomatal length was found to be a less variable and more accurately measured character than

and both yield and protein content were negatively [illegible] leaf measurements were small, that when the determinations were made on [illegible] leaves. This suggests that length of stomata or [illegible] may prove of value in selecting high yielding strains in breeding material. The plants on which the determinations were made were grown in flower pots, and it is difficult to maintain a group of lines under uniform conditions in the greenhouse. Improved methods aiming at a more uniform environment are being developed. Such improvements should result in more significant results between different sets of determinations.

In order to determine more exactly the nature of relationships between yield and stomatal length it will be necessary to use a group of unselected strains from one or more crosses in a further study. The data obtained in this investigation will make it possible to choose parental varieties for such a study intelligently.

The study of stomata and their relation to chromosome numbers in wheat is of interest in the light of similar studies in other genera. It is not improbable, however, that the study may have practical significance. The key to the problem of breeding for drought resistance might possibly be found in [illegible] characteristics, just as has been done in breeding for rust resistance. The elimination of all durum wheats from our [illegible] because of their low yields does not, however, indicate that this would be a promising avenue to explore.

SUMMARY.

Significant varietal differences in length and frequency of stomata were established in all tests. Stomatal length was found to be a less variable and more accurately measured character than number of stomata.

A negative relation between length of stomata and yield, and a positive relation between length of stomata and protein content was established. There is also a negative relation between stomatal frequency and protein content.

The value of stomatal length determinations, made on seedlings grown in the greenhouse, for selecting high yielding strains, was investigated. Indications are that such determinations will be useful, but further study will be necessary to determine more accurately the extent of the relationship.

Stomata are shown to decrease in length and increase in number when the moisture supply is above or below optimum for growth. It was not possible to influence stomatal length or frequency, independently of plant size, by altering the moisture supply.

A negative relation between number of chromosomes and number of stomata, and a positive relation between number of chromosomes and length of stomata were shown to exist in wheat. In this study 14-, 28-, 42- and 56- chromosome species were used.

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APPENDIX A.

Summary of Mean Stomatal Lengths and Frequencies in Leaves of Wheat Varieties in Advanced Drought Tests in 1937, 1938 and 1939

		Seedling Leaf*											Terminal Leaf*				
Variety	N.S.N.***	Frequency 1938	Length 1938	Frequency 1939	Length 1939	Frequency 2-test mean	Length 2-test mean	Frequency 1937	Length 1938	Frequency 1939^{I**}	Length 1939^{I**}	Frequency 1939^{III**}	Length 1939^{III**}	Frequency 3-test mean	Length 3-test mean	Frequency $1939^{I\&III}$ 2-test mean	Length $1939^{I\&III}$ 2-test mean
Marquis	I-0-9	16.0	75.8	17.7	78.6	16.8	77.2	49.1	63.7	32.8	57.6	34.9	58.7	38.9	60.0	33.8	58.2
Caesium	I-28-20	14.5	67.9	17.3	72.0	15.9	70.0	50.9	59.8	38.2	55.8	36.2	55.8	41.4	57.1	37.2	55.8
Caesium x Marquis	H-29-54	13.9	72.1	19.1	76.1	16.5	74.1	46.8	61.6	34.4	54.4	36.0	58.3	39.1	58.1	35.2	56.4
" x "	H-29-56	13.9	72.4	20.4	72.1	17.2	72.2	49.6	61.5	35.7	59.1	33.2	57.2	39.5	59.3	34.4	58.2
" x "	H-29-57	12.6	73.4	20.0	77.2	16.3	75.3	47.2	60.8	31.1	59.5	33.2	58.4	37.2	59.6	32.2	59.0
" x "	H-29-59	13.9	75.0	18.8	76.6	16.4	75.8	46.5	63.2	28.4	59.0	33.4	60.0	36.1	60.7	30.9	59.5
" x "	H-29-77	11.6	72.2	15.7	80.0	13.6	76.1	47.2	62.7	33.6	57.5	34.6	57.8	38.5	59.3	34.1	57.6
" x "	H-29-78	14.1	76.1	19.8	76.3	17.0	76.2	50.0	64.4	33.7	61.4	33.1	60.0	38.9	61.9	33.4	60.7
" x "	H-29-85	15.4	72.2	22.1	79.1	18.8	75.6	48.1	60.6	35.2	58.4	34.4	60.2	39.2	59.7	34.8	59.3
" x "	H-29-86	16.0	73.5	19.1	78.0	17.6	75.8	55.6	62.3	32.2	60.0	33.7	57.8	40.5	60.0	33.0	58.9
" x "	H-29-87	16.9	71.8	19.9	74.9	18.4	73.4	50.7	62.6	35.8	58.3	32.2	58.0	39.6	59.6	34.0	58.2
" x "	H-29-88	16.6	75.7	19.6	80.9	18.1	78.3	48.6	64.4	34.9	57.0	30.3	60.4	37.9	60.6	32.6	58.7
" x "	H-29-89	14.1	68.5	17.7	78.5	15.9	73.5	49.5	61.9	37.7	59.5	34.8	58.0	40.7	59.8	36.2	58.7
I-28-60 x Milturum	H-29-6	15.8	76.8	21.0	76.4	18.4	76.6	48.0	63.2	35.1	58.5	34.2	58.1	39.1	59.9	34.6	58.3
" x "	H-29-9	13.2	76.2	17.3	86.1	15.2	81.2	42.9	66.9	32.5	62.0	28.2	62.4	34.5	63.8	30.4	62.2
" x "	H-29-18	14.3	77.7	16.7	82.9	15.5	80.3	43.4	69.5	30.1	63.6	34.7	64.0	36.1	65.7	32.4	63.8
" x "	H-29-31	15.1	79.7	18.2	86.1	16.6	82.9	46.7	61.5	33.7	60.4	31.8	58.9	37.4	60.3	32.8	59.6
" x "	H-29-32	15.4	78.8	18.1	79.8	16.8	79.3	46.9	61.6	32.4	58.4	33.7	60.0	37.7	60.0	33.0	59.2
" x "	H-29-34	13.7	77.2	19.6	78.1	16.7	76.0	45.7	63.5	32.2	58.8	28.7	61.0	35.5	61.1	30.4	59.9
" x "	H-29-35	14.8	73.0	19.7	75.9	17.2	74.4	43.9	63.2	33.4	59.1	30.3	58.7	35.9	60.3	31.8	58.9
" x "	H-29-37	14.6	72.9	18.7	78.4	16.6	75.6	47.3	62.6	33.6	55.1	33.1	60.9	38.0	59.5	33.4	58.0
" x "	H-29-38	14.7	79.3	17.8	81.8	16.2	80.6	47.1	61.9	35.7	58.9	30.4	59.4	37.7	60.1	33.0	59.2
" x "	H-29-40	13.9	76.9	17.0	82.6	15.4	79.8	47.3	64.1	35.0	59.2	31.8	59.8	38.0	61.0	33.4	59.5
" x "	H-29-41	16.3	80.2	16.8	80.5	16.6	80.4	50.5	62.0	33.3	58.7	31.2	57.7	38.3	59.5	32.2	58.2
" x "	H-29-47	15.4	77.1	16.9	78.6	16.2	78.0	51.1	60.9	35.8	60.0	34.3	58.9	40.4	59.6	35.0	59.4
Apex	I-36-102	13.6	72.4					49.0	64.2	35.1	60.0	32.8	59.0	39.0	61.1	34.0	59.5
Canus	S-34-1	14.0	75.5					48.6	62.2	34.4	58.6	32.3	59.2	38.4	60.0	33.4	58.9
Double Cress	I-28-60	16.0	75.2					41.5	65.9	36.3	60.6	32.0	60.6	36.6	62.4	34.2	60.6
Milturum .0321	I-28-14	15.1	69.9					67.1	60.8	34.5	57.4	38.3	60.5	46.6	59.6	36.4	59.0
Red Bobs	I-0-18	16.5	68.5					55.7	55.4	42.5	52.3	40.5	53.0	46.2	53.6	41.5	52.6
Thatcher	I-34-15	16.2	79.2					39.9	65.7	34.8	61.4	30.9	59.5	35.2	62.2	32.8	60.4
Luteccens	I-36-86									32.3	58.2	35.4	56.9			33.8	57.6
Regent	I-36-135									34.7	58.8	32.1	59.5			33.4	59.2
Caesium x Marquis	H-37-2									33.0	54.7	26.3	58.8			29.6	56.8
" x "	H-37-5									35.1	60.2	32.1	58.0			33.6	59.1
" x "	H-37-9									35.0	57.0	28.3	56.7			31.6	56.8
" x "	H-37-10									35.0	56.3	32.4	58.0			33.7	57.2
" x "	H-37-11									31.2	58.6	29.8	62.5			30.5	60.6
" x "	H-37-14									32.2	60.3	35.6	58.7			33.9	59.5
" x "	H-37-16									32.5	58.5	34.0	57.1			33.2	57.8
" x "	H-37-20									29.7	61.2	30.6	58.7			30.2	60.0
" x "	H-37-24									33.3	58.8	32.9	58.8			33.1	58.8
" x "	H-37-25									37.1	56.0	33.5	57.2			35.3	56.6
" x "	H-37-30									33.6	57.5	34.8	56.2			34.2	56.8
" x "	H-37-36									37.5	55.6	34.4	56.2			36.0	55.9
Marquis x Caesium	H-37-40									34.7	53.7	30.6	56.1			32.6	54.9
Reward x Caesium	H-37-41									34.3	55.0	32.8	53.6			33.6	54.3
" x "	H-37-42									37.6	56.5	38.4	55.4			38.0	56.0

Variety	N.S.N.***	Frequency 1938	Length 1938	Frequency 1939	Length 1939	Frequency 2-test mean	Length 2-test mean	Frequency 1937	Length 1938	Frequency 1939^{I**}	Length 1939^{I**}	Frequency 1939^{III**}	Length 1939^{III**}	Frequency 3-test mean	Length 3-test mean	Frequency $1939^{I\&III}$ 2-test mean	Lengt $1939^{I\&II}$ 2-tes mean
Reward x Caesium	H-37-50									34.9	56.0	31.6	57.2			33.2	56.6
" x "	H-37-52									36.4	55.0	38.7	56.3			37.6	55.6
" x "	H-37-53									32.2	55.0	35.7	54.4			34.0	54.7
" x "	H-37-55									34.7	58.0	35.9	58.0			35.3	58.0
Baart	I-33-9	12.3	79.5					48.9	63.1								
Ceres	I-25-1	15.5	75.3					50.6	62.7								
Ceres x(Hope x Florence)	I-37-5	18.8	78.3					51.0	61.0								
" x " x "	I-37-6	14.7	76.5					49.2	61.3								
Erythrospermum	I-36-129	14.5	72.7					48.8	60.8								
Garnet	I-25-13	12.0	80.4					46.2	61.7								
Hard Federation	I-28-35	13.7	74.8					50.0	61.6								
Hope	I-37-7	13.5	74.7					42.6	64.7								
Hope x Reward	I-37-11	16.0	77.3					52.9	66.0								
Hordeiforme .0189	I-36-132	23.1	64.1					60.7	56.9								
H-44-24 x Reward	I-37-12	16.5	76.2					49.5	63.1								
Iumillo	I-36-104	18.3	65.3					56.2	57.7								
Milturum .0274	I-28-25	15.6	72.0					50.6	60.5								
Mindum	I-36-100	24.0	66.1					55.9	56.0								
Nordstrom	I-37-1	16.0	69.7					53.0	58.9								
Onas	I-33-13	13.6	70.8					50.3	58.3								
Pelissier	I-37-8	19.9	67.8					54.6	58.8								
Reliance	I-29-4	15.0	76.7					45.7	62.6								
Renfrew	I-0-20	15.2	75.6					54.8	63.3								
Reward	I-25-21	17.2	75.8					50.4	63.7								
Sikora	I-36-105	11.0	76.3					49.1	62.4								
Marquis x Caesium	H-29-48	15.3	68.3					51.6	61.5								
Caesium x Marquis	H-29-50	14.3	71.9					52.0	57.2								
" x "	H-29-52	16.1	71.8					51.7	60.9								
" x "	H-29-58	14.1	72.0					47.3	63.5								
" x "	H-29-61	14.6	73.7					50.3	63.6								
" x "	H-29-62	14.1	73.5					49.8	64.8								
" x "	H-29-76	13.3	75.3					46.6	61.7								
" x "	H-29-81	15.7	69.0					46.4	64.7								
" x "	H-29-82	16.3	71.5					50.3	61.9								
" x "	H-29-83	15.3	76.5					49.8	62.6								
" x "	H-29-84	12.4	71.9					49.2	64.6								
I-28-60 x Milturum	H-29-10	14.3	76.4					45.6	61.4								
" x "	H-29-16	14.1	72.6					43.4	61.7								
" x "	H-29-17	15.4	77.8					46.9	59.3								
" x "	H-29-39	13.6	81.0					46.8	67.8								
" x "	H-29-42	14.8	80.3					49.3	64.8								
" x "	H-29-43	14.7	79.0					46.5	63.0								
" x "	H-29-44	13.4	80.6					44.5	65.7								
" x "	H-29-45	16.4	78.1					49.4	63.4								
" x "	H-29-46	14.6	81.7					50.6	63.5								
Reward x Caesium	H-29-27	11.5	68.7					49.3	62.2								
" x "	H-29-79	13.2	73.4					46.4	60.2								
" x "	H-29-80	13.5	74.3					48.6	62.2								

* To convert lengths to microns multiply by 0.952 and to convert frequencies to number per square millimeter multiply by 1.420.

** 1939^{I} and 1939^{III} refer to determinations made in replicate I and replicate III respectively of the 1939 tillering test.

*** University of Alberta Nursery Stock Number.

APPENDIX B.

Summary of mean stomatal frequencies in sub-terminal leaves of 86 wheat varieties in preliminary drought tests 1939. (frequencies per unit leaf area)

Variety	N.S.N.	Frequency			
		Edmonton^{I}	Edmonton^{III}	Castor^{IV}	Mean
Reward x Caesium	H-39-52	37.5	35.6	24.0	32.4
" x "	H-39-57	30.2	27.5	31.1	29.6
Caesium x Marquis	H-39-14	34.9	28.2	25.6	29.6
Lutescens	I-36-125	34.0	32.2	24.4	30.2
Strube	I-36-94	37.8	33.3	28.3	33.1
Caesium x Marquis	H-39-22	29.2	28.5	24.5	27.4
Type 14	I-38-4	31.0	28.1	33.0	30.7
Caesium x Marquis	H-39-26	33.9	30.3	28.0	30.7
Graecum	I-36-130	36.7	34.0	28.6	33.1
T. turgidum	I-36-45	48.5	41.7	39.9	43.4
Caesium x Marquis	H-39-18	32.0	28.6	26.5	29.0
" x "	H-39-15	32.2	28.7	28.6	29.8
" x "	H-39-19	39.5	34.5	29.4	34.5
T. vulgare	I-36-52	35.5	38.0	33.0	35.5
Erythrospermum	I-36-73-1	37.5	38.9	40.8	39.1
I-28-60 x Milturum	H-39-31	32.0	29.7	24.8	28.8
Belokolska	I-36-71-1	39.8	40.3	37.0	39.0
Ceres	I-25-1	31.9	32.3	28.7	31.0
T. vulgare	I-36-47	32.3	31.6	29.2	31.0
Belokolska	I-36-71-2	45.0	41.7	35.9	40.9
Canus x Caesium	H-39-28	35.0	34.3	29.5	32.9
T. vulgare	I-36-53-1	32.7	30.2	32.0	31.6
I-28-60 x Milturum	H-39-45	27.3	24.2	27.7	26.4
Caesium x Canus	H-39-2	31.4	25.2	23.3	26.6
Caesium	I-28-20	39.5	37.0	29.3	35.3
Caesium x Marquis	H-39-11	29.0	31.7	25.4	28.7
T. vulgare	I-36-61	32.8	31.2	27.8	30.6
I-28-60 x Milturum	H-39-40	33.0	31.1	30.2	31.4
Caesium x I-28-65	H-39-6	32.1	31.1	28.7	30.6
I-28-60 x Milturum	H-39-42	32.5	31.9	29.4	31.3
T. vulgare rigidum	I-36-54	34.8	31.4	30.4	32.2
Reward x Caesium	H-39-51	38.0	36.0	31.1	35.0
Erythrospermum	I-36-40	35.2	28.3	27.6	30.4
I-28-60 x Milturum	H-39-39	33.9	31.3	28.2	31.1
Canus x Caesium	H-39-27	30.1	31.7	27.2	29.7
Caesium x Marquis	H-39-25	33.2	20.3	27.5	30.3
Hordeiforme .010	I-36-22	46.4	47.9	42.3	45.5
T. vulgare rigidum	I-36-50	35.1	35.5	28.6	33.1
Reward x Caesium	H-39-56	36.2	33.5	28.4	32.7
" x "	H-39-55	38.2	33.3	29.4	33.6
Extra Colben	I-36-75	37.2	34.2	33.4	34.9
I-28-60 x Milturum	H-39-16	34.3	32.7	30.2	32.4
" x "	H-39-36	30.3	27.1	28.6	28.7
Caesium x Canus	H-39-3	35.4	30.8	26.3	30.8

		Frequency			
Variety	N.S.N.	Edmonton I	Edmonton III	Castor IV	Mean
C.518	I-38-6	37.5	32.8	29.2	33.2
Caesium x Canus	H-39-1	38.0	36.2	27.0	33.7
I-28-60 x Milturum	H-39-34	30.9	32.7	27.8	30.5
Type 13	I-38-3	34.7	36.1	30.8	33.9
Caesium x Marquis	H-39-24	35.8	30.8	24.7	30.4
" x "	H-39-20	33.7	32.5	26.5	30.9
I-28-60 x Milturum	H-39-35	29.9	30.2	32.6	30.9
Caesium x Marquis	H-39-23	31.5	33.2	28.7	31.1
" x "	H-39-13	25.9	28.1	27.2	27.1
Red Bobs	I-0-18	39.7	37.9	37.0	38.2
Hannsteen	I-39-1	33.7	30.3	29.8	31.3
I-28-60 x Milturum	H-39-43	32.9	34.4	31.7	33.0
Caesium x Marquis	H-39-21	34.5	26.8	29.2	30.2
" x "	H-39-10	30.1	30.4	24.4	28.3
Belokolska	I-36-71-3	46.1	42.3	40.2	42.9
Caesium x Marquis	H-39-8	33.6	32.4	29.7	31.9
T. vulgare	I-36-53-2	31.6	28.4	26.8	28.9
Caesium x Marquis	H-39-9	34.8	35.5	29.0	33.1
" x "	H-39-17	33.3	31.7	28.9	31.3
T. vulgare	I-36-53-3	31.5	25.8	22.9	26.7
C.409	I-38-5	31.6	35.4	34.6	33.9
T. vulgare rigidum	I-36-49	35.8	33.7	30.0	33.2
Marquis	I-0-9	32.3	29.9	31.6	31.3
Nordstrom	I-37-1	35.3	32.6	25.3	31.1
Reward x Caesium	H-39-59	33.6	30.4	29.9	31.3
T. vulgare	I-36-64-2	43.1	45.1	37.9	42.0
Marquis x Caesium	H-39-50	30.3	32.3	31.7	31.4
T. vulgare	I-36-65	32.6	36.8	32.2	33.9
I-28-60 x Milturum	H-39-33	32.7	30.1	27.4	30.1
Golokol	I-36-78	37.1	34.6	25.6	32.4
Coerulescens	I-36-72	36.8	33.5	29.8	33.4
I-28-65 x Caesium	H-39-46	29.6	30.1	31.7	30.5
T. vulgare	I-36-64-1	39.0	35.8	32.8	35.9
T. "	I-36-54	30.7	30.1	30.1	30.3
Caesium x Marquis	H-39-7	34.6	27.9	31.2	31.2
8A	I-38-7	34.8	34.9	33.3	34.3
Erythrospermum	I-36-73-2	39.3	37.6	34.4	37.1
T. vulgare rigidum	I-36-51	33.3	34.3	29.9	32.5
Caesium x I-28-65	H-39-4	32.0	25.2	26.7	28.0
Caesium x Marquis	H-39-12	31.6	30.6	29.4	30.5
Noya	I-36-92	39.6	35.4	32.2	35.7
Caesium x Marquis	H-39-16	38.5	37.5	35.2	37.1

APPENDIX C.

Summary of mean stomatal lengths and frequencies in terminal leaves of 52 wheat varieties in 1939 wheat garden. (frequencies per unit leaf area; lengths in micrometer units)

Variety	1939 Plot No.	Frequency	Length
Varieties having 14 chromosomes:			
Einkorn	1	57.8	43.8
Varieties having 28 chromosomes:			
Velvet Don	21	43.4	
Melanopus	20	43.8	
Russian 123	13	44.7	
Albidum .0604	23	46.4	
Pentad	11	45.0	
Iumillo	12	46.3	
C.I.7513	19	39.3	48.6
[redacted]	[redacted]	[redacted]	[redacted]
Pelissier	14	43.9	
Polish	9	47.3	46.8
Sigfusson	15	42.5	
Mindum	35	47.7	
Hordeiforme .010	34	52.1	46.0
Kubanka	33	45.9	
Mindum	30	46.9	
Hordeiforme .0189	28	44.3	
Mindum x Pentad	40	41.1	
N.D. Kahla no.5529	39	43.6	
T. turgidum D.371	331	52.4	42.3
T. persicum	276	48.5	
T. persicum (Timopheevi)	299	42.8	52.8
T. persicum	275	41.4	52.9
Common Emmer	4	44.1	50.3
Alaska	10	45.7	48.0
Aegilops ovata L.	309	54.6	
Aegilops ovata	307	56.3	48.3
T. dicoccum pers.	453	41.0	
Varieties having 42 chromosomes:			
Albidum .0721	87	40.9	
Dicklow	93	44.9	
Marquis	142	32.7	58.6
Garnet	127	37.1	
Red Bobs	135	42.7	52.6
T. vulgare D.381	342	36.6	
Kenya	472	36.8	
Double Cross	200	33.2	58.9
Milturum .0321	184	42.7	53.8
Common Spelt	7	32.7	58.2

Variety	1939 Plot No.	Frequency	Length
Baart	117	34.1	
Pilcraw	108	36.3	
Pacific Bluestem	107	36.3	
Little Club	56	37.8	53.6
Hybrid 143	55	37.0	
Aegilops turcomanico	308	50.4	
T. vulgare D.433	348	35.2	
C.518	436	34.5	
C.409	437	32.3	
8A	439	34.8	
Type 14	440	31.9	
Type 13	441	37.0	
Gular	447	36.2	
Varieties having 56 chromosomes:			
56 Chromosome (short)	315	31.4	65.5
56 Chromosome (tall)	316	34.2	58.9

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